

A Vision for Future Software

Open Source and Design Thinking at NASA

Jay Trimble
NASA Ames Research Center

Frontiers 2017



Personal Milestones



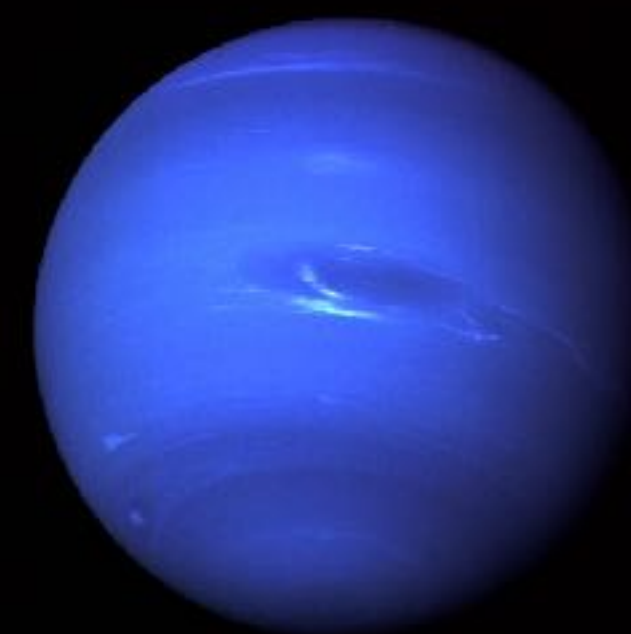
1960's



1981

NASA JSC Intern

NASA Johnson Space Center



1989

Science Ops
Voyager Neptune

NASA Jet Propulsion Laboratory



1994

Lead Ops Director
Space Radar Lab 1

NASA Ames Research Center

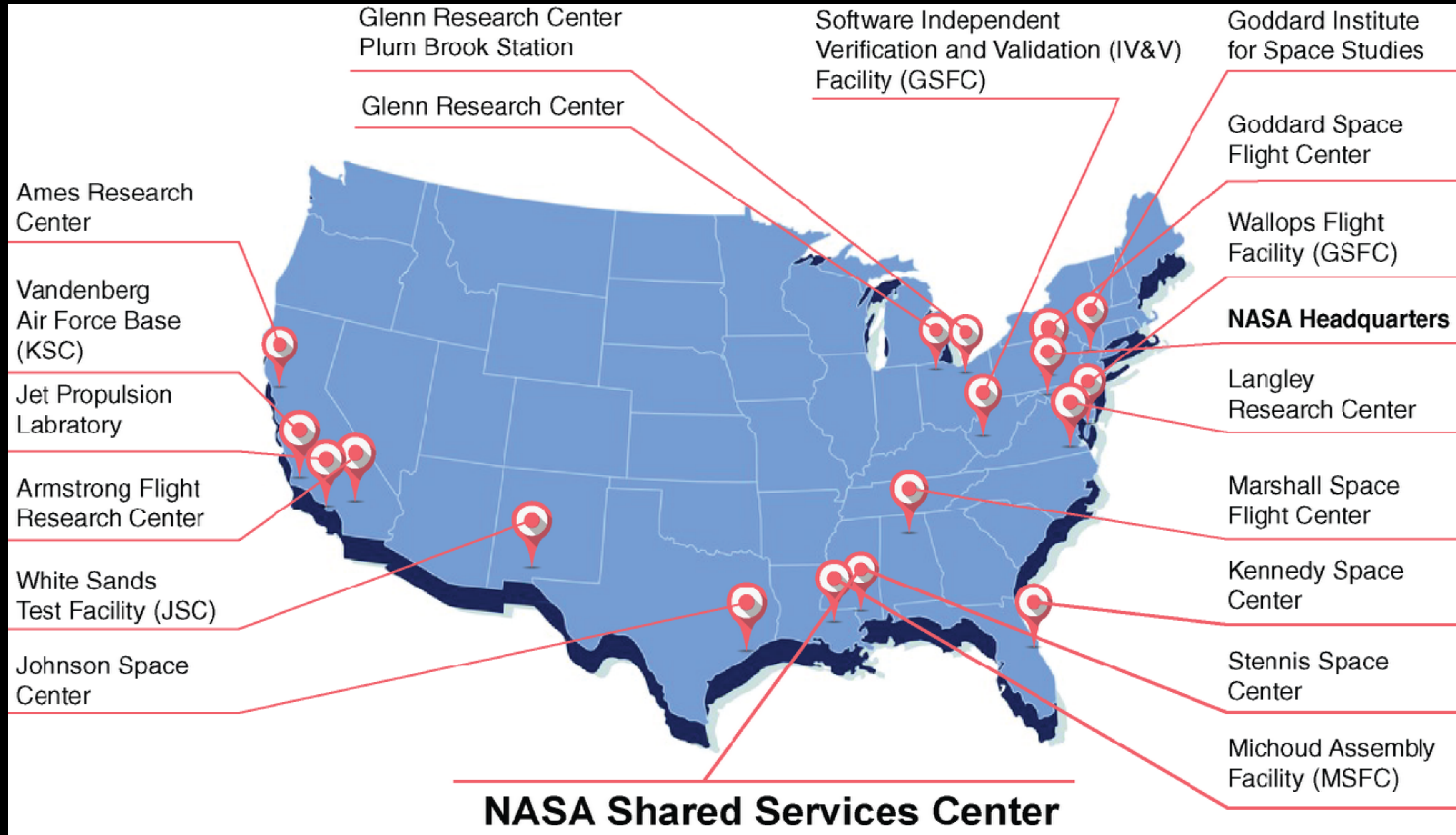


Now

Lunar Rover MOM



NASA Centers





Mission Control: The Icon



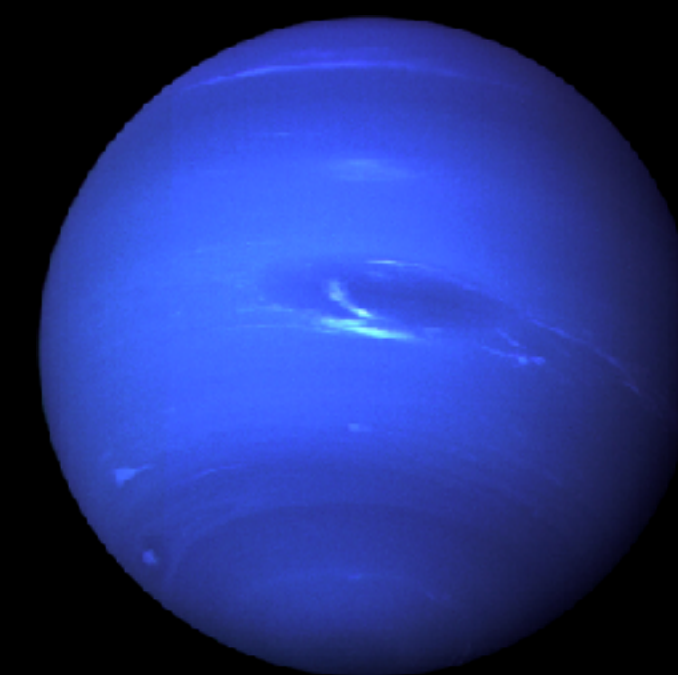
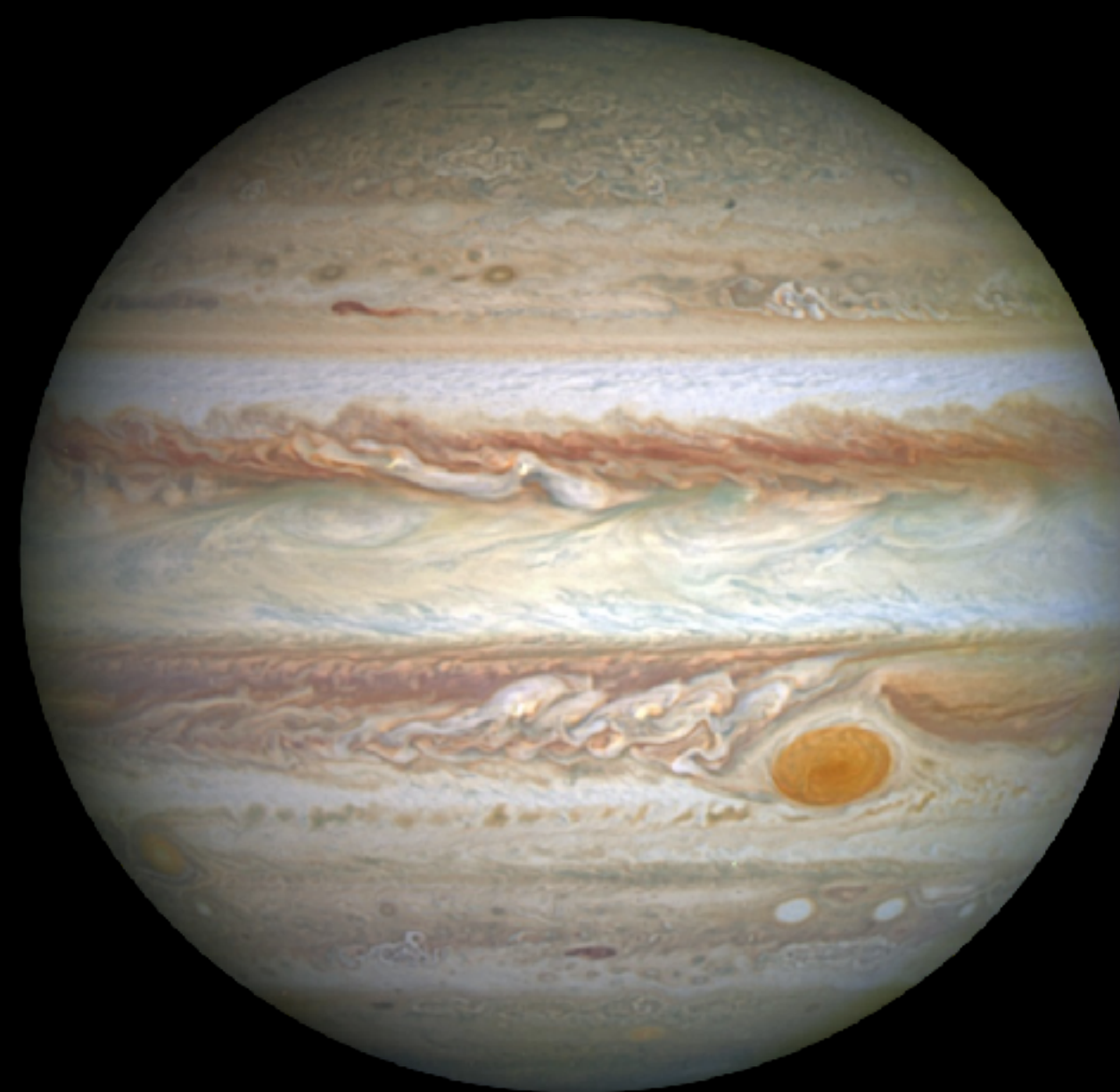
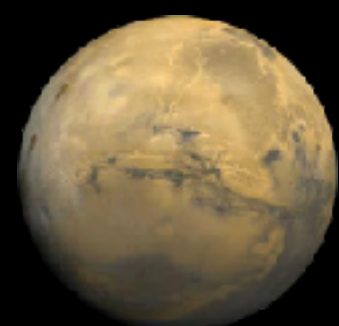


Mission Control for Mars Rovers





The Light Speed Constraint



Earth-Moon
~6 - 25s

Mars
~14 - 40 Min

Jupiter
~80 Min

Neptune
~8 hours



Mission Control v. Star Trek

- NASA

- Flight Director
- Systems
- Trajectory
- Payloads/POCC
- INCO



- Star Trek

- Captain (Kirk, Janeway, Picard, Cisco,...)
- Engineering (Mr. Scott)
- Navigation (Chekov)
- Science Officer (Spock)
- Communications (Uhura)





Mission Control Famous Calls





Mission Control Famous Calls





Mission Control Famous Calls





Houston Mid-1980's

The Mission

Repair a malfunctioning satellite

In orbit capture and repair has not been done

It's made possible by the Space Shuttle





The First Epiphany

0 DAY 0 4 6

F/V 13/009 FSS CONTROL RR3408A CH020

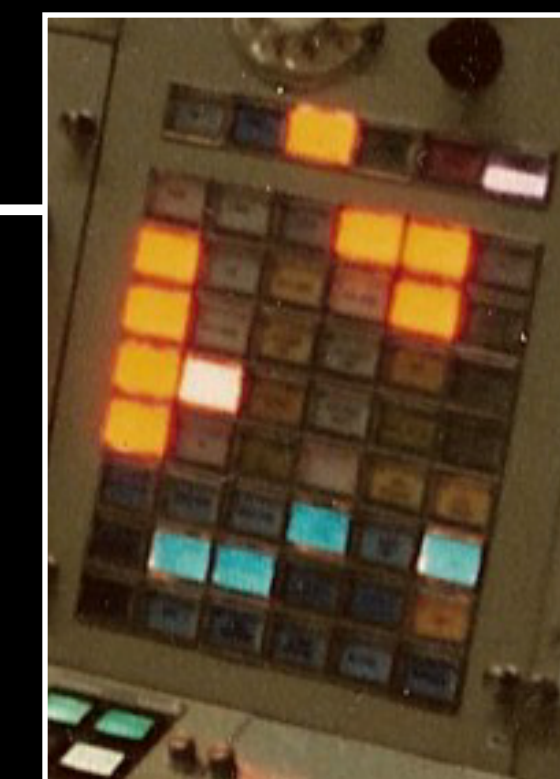
CGMT 46:19:11:11 DMET 0:00:00:00 SITE MIL 01 188 GN 0
RGMT 46:19:11:11 U/D RATE 1 SM 64 BF 0

MECHANISM SELECTION		CONFIGURATION		TELEMETRY	
		ON	OFF	AMPS	TEMP
BERTH LAT 1	1			SCIU 0.56	22
2	2			MSB 0.06	23
3	3			MPC 3.6	
UMB MAIN	4			DPC 0.1	
HEATER	5			FSS LCKR 1	8%
RET LAT KEEL	6			2	8%
PORT 7	7				
STBD 8	8				
ROTATOR	9				
PIVOTER	10			PCU	26
TRANSLATOR	11			PDSU	22
PLAT LOCK	12				
DESELECT	13				
HEATERS (SSP)				FMDM 0.90	3%
ENA AMPS				FMDM BOX A	-99%
FSS 0.1					
SMM 0.1					
MACS 0.1					
OVERRIDE					
ENABLE 14%					
DISABLE 15					
DEU				DISP	MF
1				2200	SM
2				1	SM
3				5	05
4				5	05

13 YB4 001 9 0001 1 SEC 1

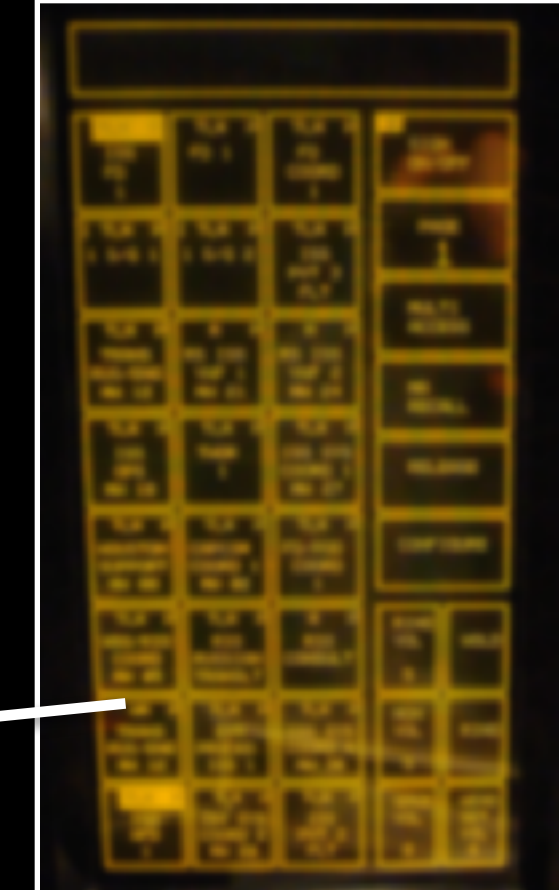


SCIU A ON	MSB A ON	MPC A ON	DPC A ON	HEATER FSS ON	
SCIU A OFF	MSB A OFF	MPC A OFF	DPC A OFF	HEATER FSS OFF	
SCIU B ON	MSB B ON	MPC B ON	DPC B ON	LOCKER FSS ON	
SCIU B OFF	MSB B OFF	MPC B OFF	DPC B OFF	LOCKER FSS OFF	
FLY-013 VEH-000 REV-A					
		MPC ENABLE	DPC ENABLE		
		MPC DISABLE	DPC DISABLE		





Evolution





Pasadena Early 1990's

The Mission

Earth Observations Using
Synthetic Aperture Radar

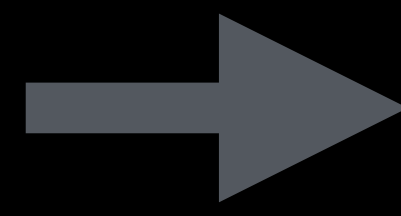
Two missions on Space
Shuttle Endeavor



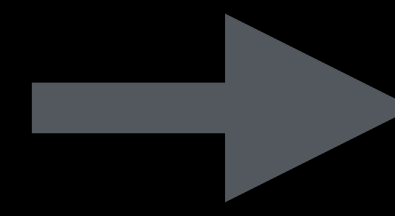


The Second Epiphany

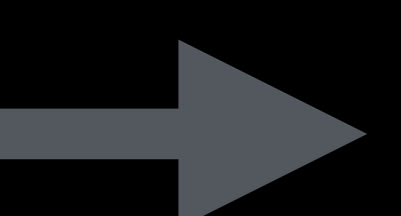
Write software requirements



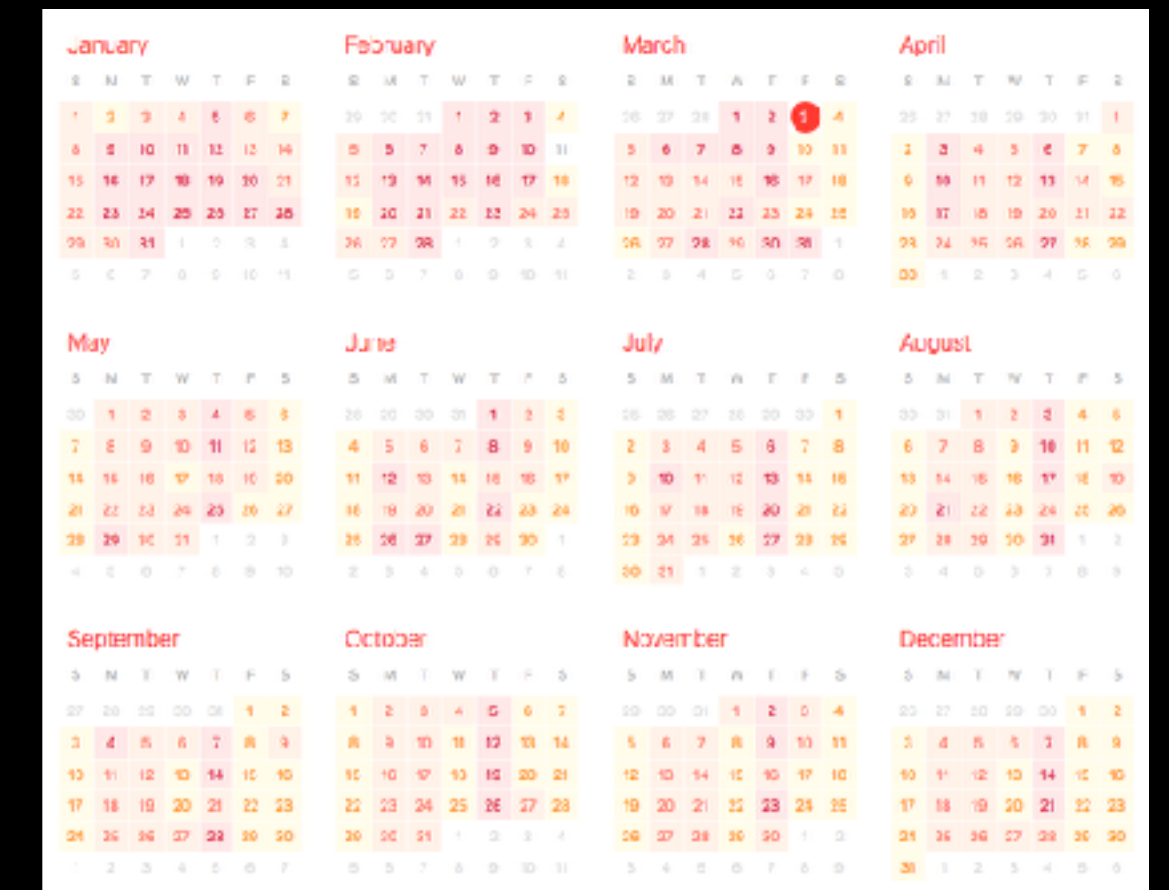
Customer signs requirements



Expectations and mental models diverge



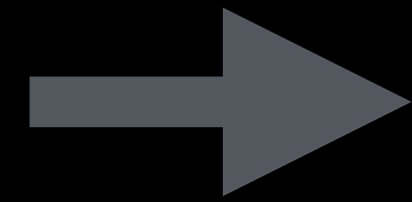
MOS shall track the orientation of the solar panels with respect to Sun (+/- TBR arcmin)



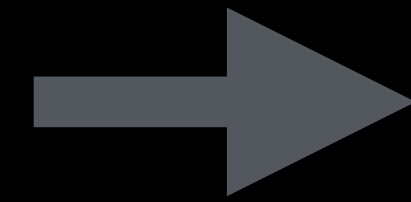


Expectations Meet Reality

About to get a look



Users see the software



Why this reaction?





There must be a better way

Follow the (as yet undefined for us) road to user centered agile or, take a long vacation



Early 2000's Mars Rover Ops

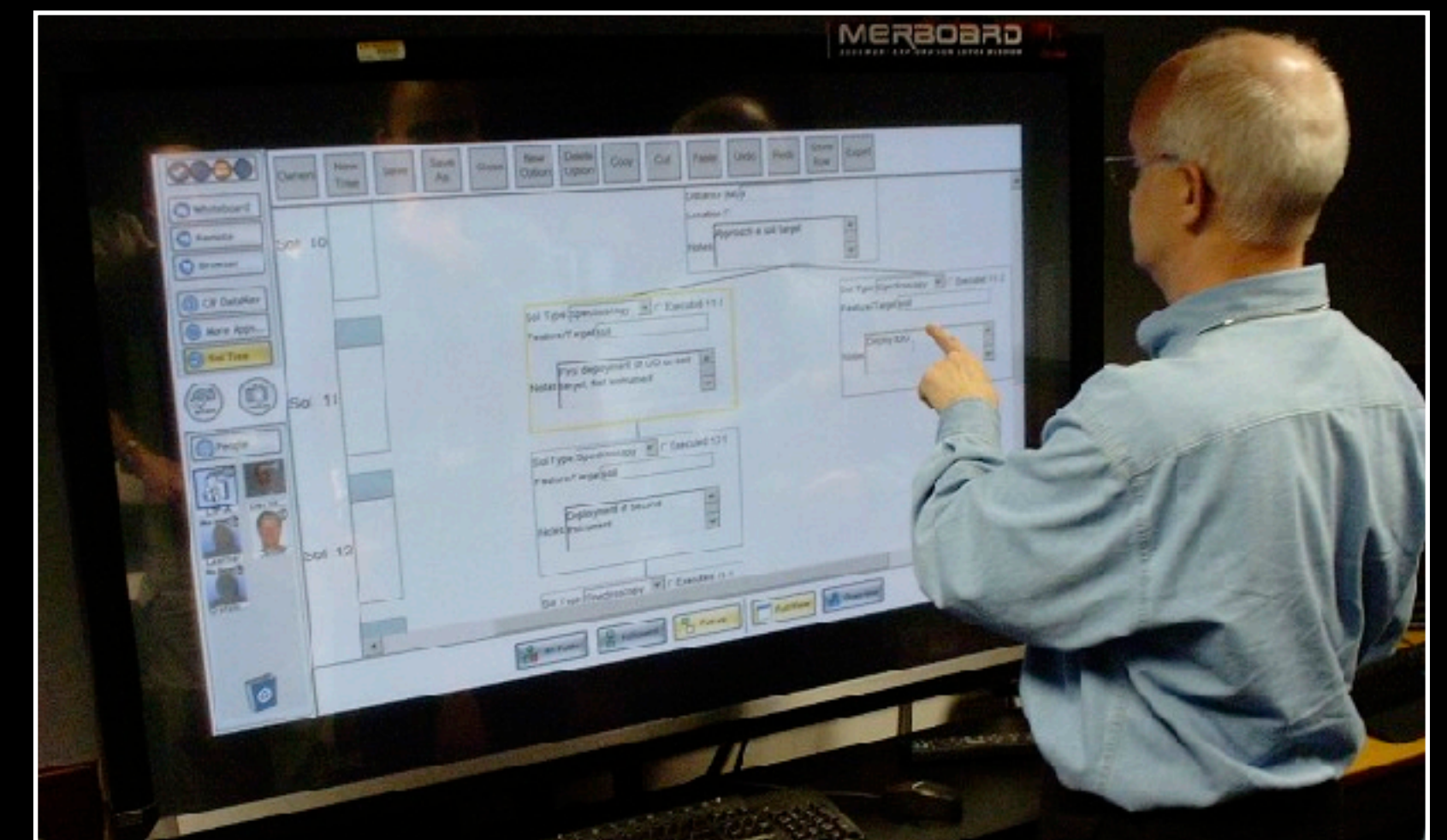
The Mission

Mars Exploration Rovers (JPL)

Human Centered Computing
(ARC)

We proposed methods, not
specific solutions or tools

We called it Human Centered
Computing, inspired by Don
Norman, The Invisible Computer



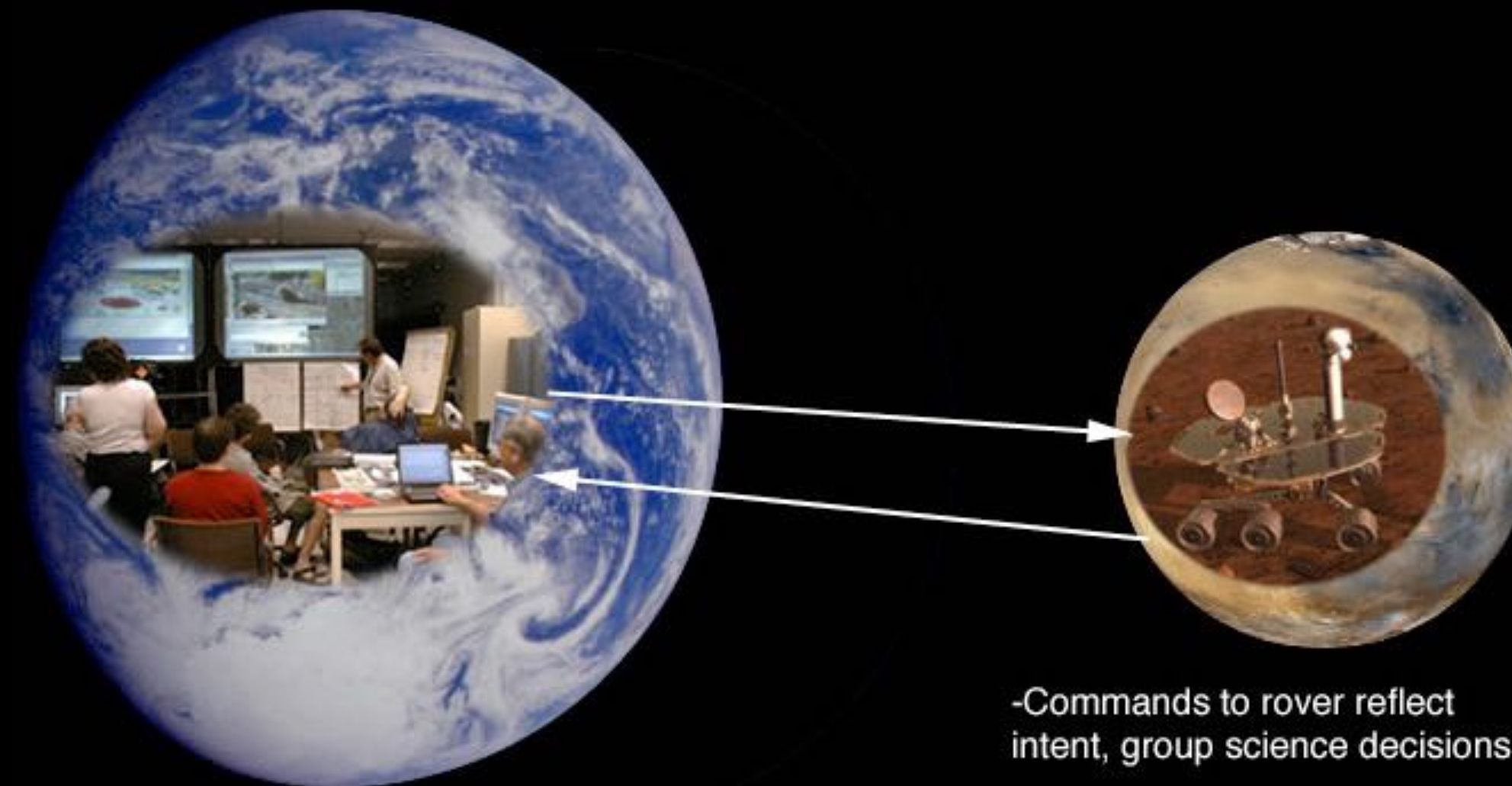


Mars Exploration Rover Scenario

Users on Earth

Rover on Mars

Max round trip light
time ~40 min



- Human Science Team with Computer tools
- Intent, Qualitative Assessment, Judgement,
- Science Priorities, Resource Management

-Commands to rover reflect intent, group science decisions



Acceptance

To fund MER HCC, we had to “sell” the ideas to our funders at NASA Ames, to the Mars Exploration Rover Project at JPL and to the users

We focused on outcomes and touched on the methods using analogies

Easier to market an artifact or a result than an idea

Mental model example - Ethnography = User observations - what people say and what they do are often different. How often do you exercise?

Goals - Mission productivity, communications, safety

Note no mention of design thinking, this is 2000



Key Lessons so far

This is a small community and most people know each other

Each mission is its own community, somewhat like the cast in a performance

Speak the stakeholders language

Be careful with generalizations like “the invisible computer” or software that adapts to users rather than the other way around

Most of the stakeholders care only about what your product or method does for their mission

Most of users don't care about design, but they may care about the results

Users who are used to a way of doing things, even an inefficient way, will resist change. Don't give them change unless it adds significant value.

Don't go against established conventions, no change for change's sake, use established, mental models

Do not try to take away existing tools. Give them new tools in shadow mode.

Be careful about getting too excited about your cool new technology



Next

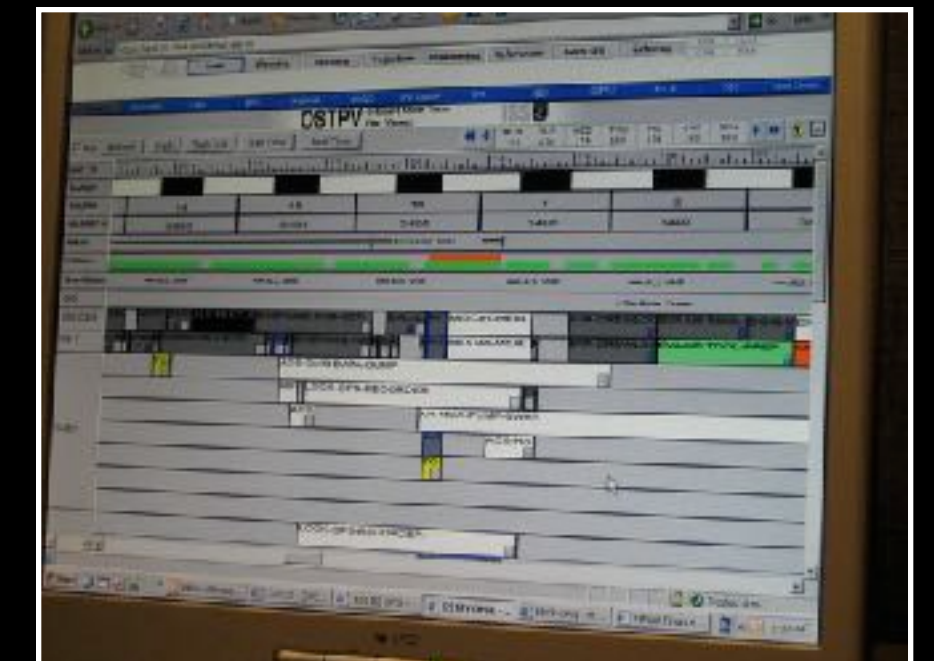
We now believe we need new technology, not just methods and process

So we embark on a new course and instead of proposing methods we propose tools...



We are trying to “fix”

Multiple heterogeneous applications create walls, turning users into integrators





The Selling Points

Decrease Cost

Save on maintenance by retiring existing applications, make the users productive

Empower the users

Compose your own displays without programming, all your stuff in one place

Top Down v. Bottom Up

The top provides the funding

The Bottom provides the advocacy (remember this is a small community)

The problem that we could not see yet

The management funded the project based on the retirement of existing applications

Users are open to new technology but less so when they are told that they are going to lose the current capability on which they depend



Participatory Design

Designers facilitate design process, users are domain experts

We used The Bridge Method

Built a shared language

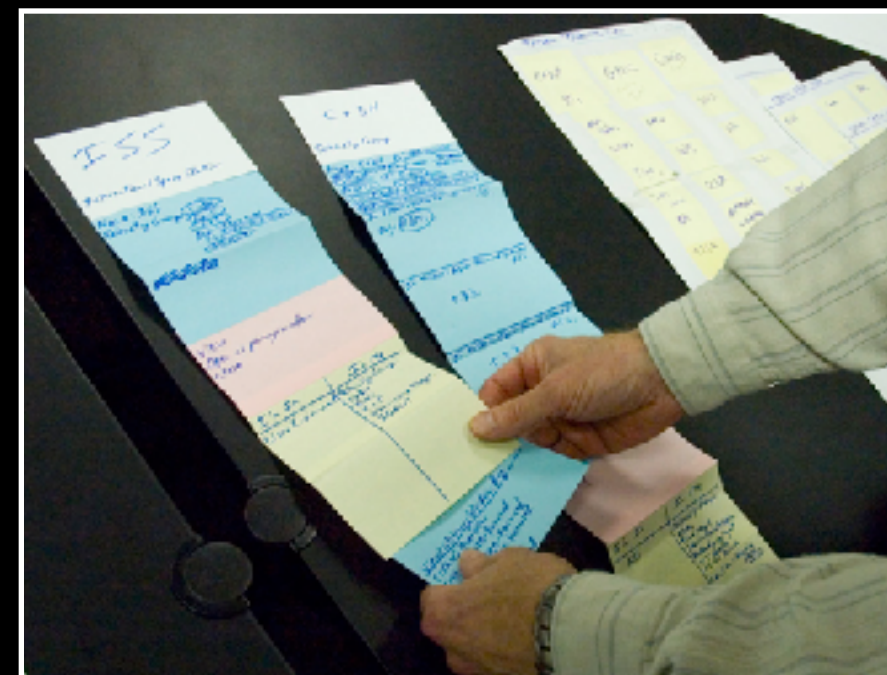
Built shared mental models

Enabled us to design solutions with users

Created a tight bond between the design team and participatory users

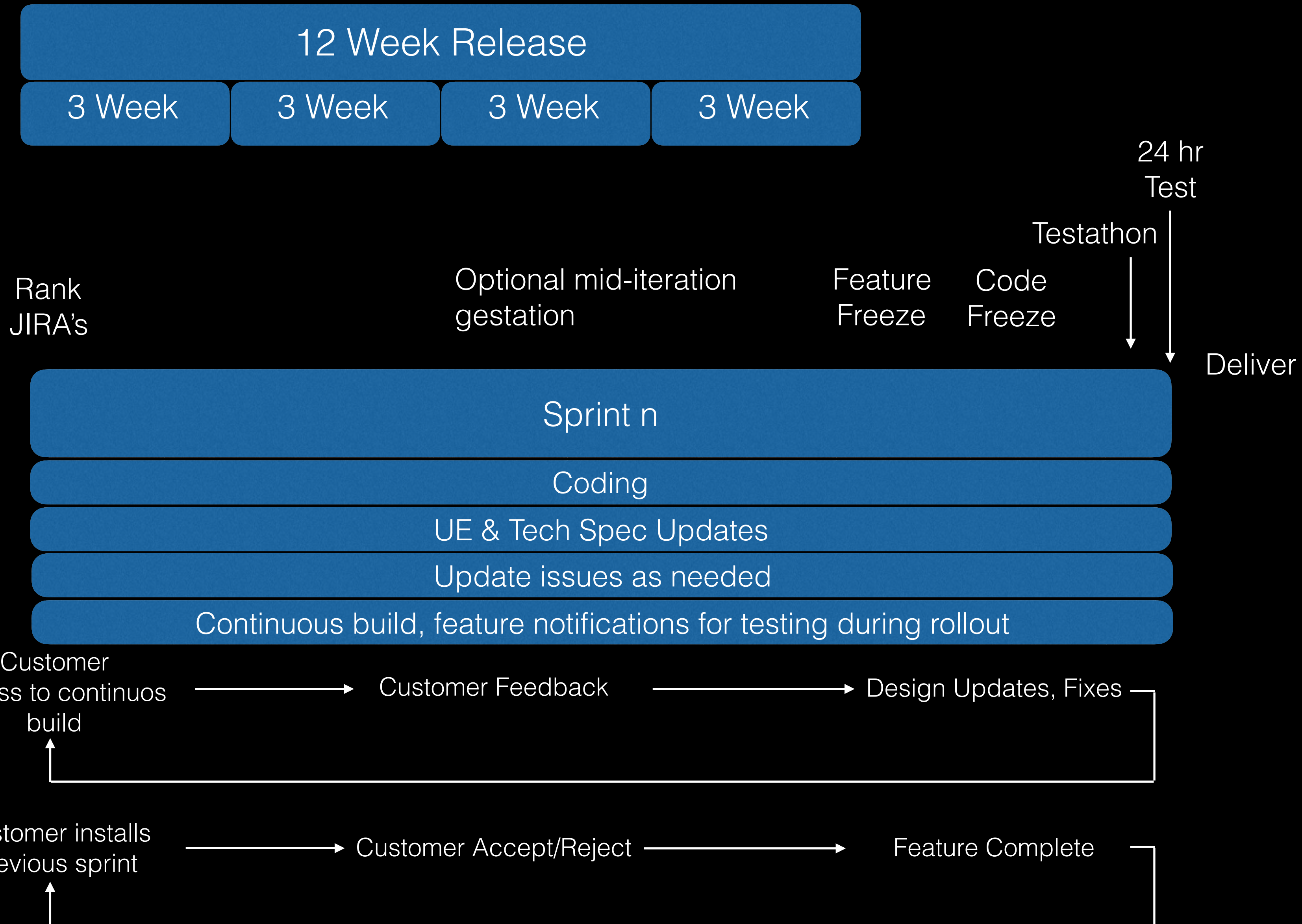
Shared ownership

Created an us v. them between the participatory team and the larger user community





Agile User Centered Design

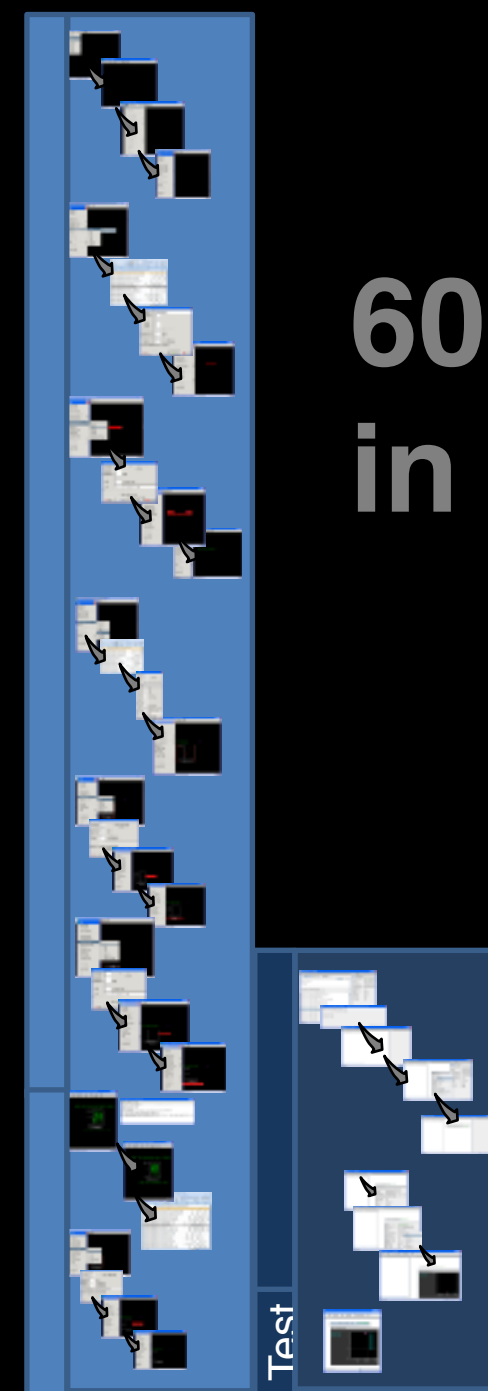




Did we help the users?

Process steps

What actions does it take to build and test a display?



**60% reduction
in steps**

**80% reduction in
manual entry**

Manual data entry is the primary
source of errors / risk

	Legacy	MCT
Steps	20	8
Manual data entries	5	1
External tools used	1	0

Process time

How long does it take to accomplish those
steps?



**90% reduction
in time**

	Legacy	MCT
Minutes to complete	65	6





Key Lessons

Design is not enough

End user composition alone is not enough, it must be mixed with the specific job enabling features that users want. The combination is powerful.

The term end user composition is nerdy and does not grab people, the popular lexicon on this shifts... “mashups,” “dashboards” and can confuse the message

Unknown cultural differences can have a big impact - our first user test, though we stated it as such, was thought by users to be the final software because this is the only mental model they had

New capabilities take a long time to catch up to “old” capabilities, benefits must outweigh the inconvenience

Don’t take away “old” capabilities, let new co-exist with old in shadow mode, for a period of time

Customers will map what you say into their own expectations, creating a mental model that varies across groups and that may be unknown to the design team

Show constant progress, make it visible and accessible

If it’s not easy, people won’t even try it

Customers want and expect new capabilities, they also want all of their legacy capabilities

Openness increases with time and use

A new mental model, even a better one, at first will be confusing to users



It's all so simple

Succeed

Know who your stakeholders are, focus

Fail

Try to solve too many problems for an undefined stakeholder base

We did better creating generalizations from instances than creating instances from generalizations - start by solving real problems not generalizations



Rebuilding

The desktop version is ultimately cancelled

We rebuild, our funders are now in California



New Stakeholders

Jet Propulsion Lab

Multi-Mission Ground Systems

Multiple missions use the software over time, at many NASA centers

NASA Ames Research Center

Resource Prospector

Successful Mission

Jet Propulsion Lab

Many Flight Projects

Each one concerned about success of their mission

Open Source Community

NASA, Commercial, Other

The success of their project



Stakeholder Language

User Test

Our users mental model in the early 2000's was that software is delivered and that's what you get (remember those inflexible displays). We conducted a user test on early software with unforeseen consequences

Prototype

A designer thinks of a prototype as a question rendered as an artifact, the expectation is that there will be many

A system engineer thinks of a prototype as a risk reduction exercise to buy down risk associated with system requirements, expectation is that there will be few because they tend to be expensive

Demo, Test

Popular mental models, such as dashboards and mashups affect user perception

Say it then sim it



Mental Model Map Example

System Engineering

Requirements (tendency
fewer ideas)

Prototypes for Risk Reduction,
typically few

Review

Build

Train, Fly

Design Thinking

Observations
Ideation
Synthesis (more ideas)

Prototypes - questions rendered
as artifacts, typically many

Try/Use ("Say it then sim it")

Iterate

Train, Fly



Open MCT

Open Mission Control Technologies

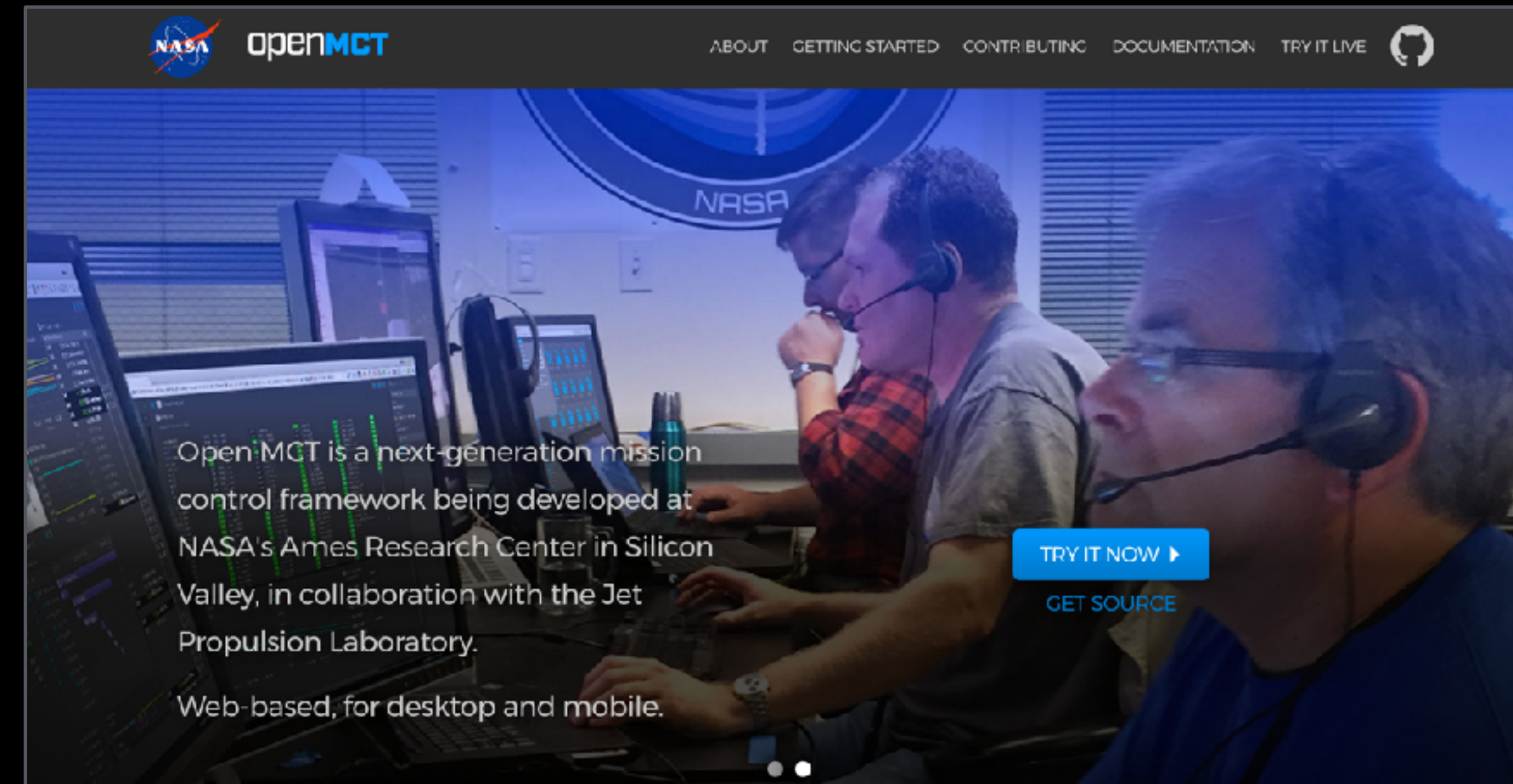
Goals

Provide users with an all your data in one place solution

Empower users to compose their own displays

Create new opportunities for collaboration and community involvement using open source

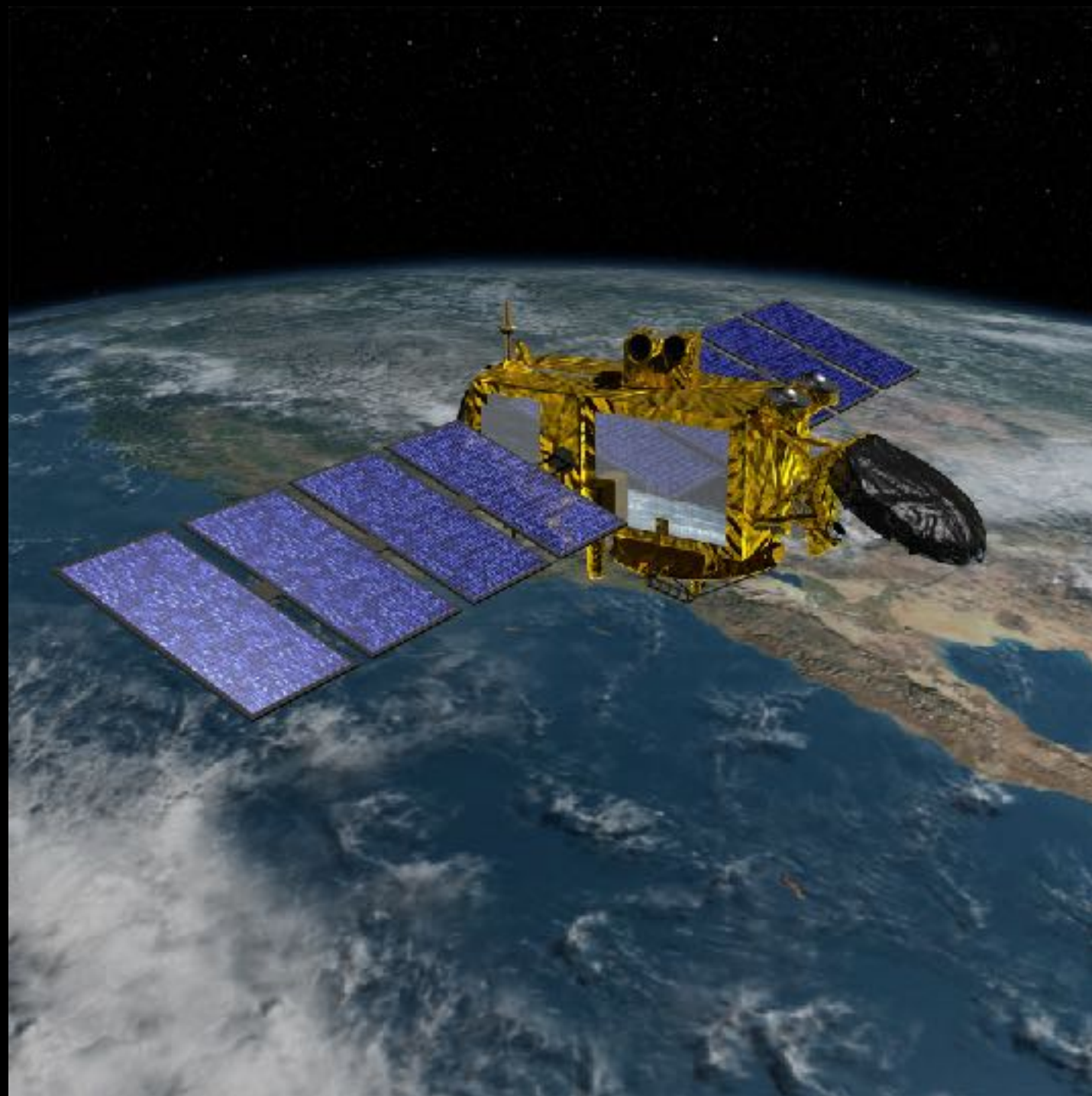
Take what has been a closed and hence mysterious world and open it up



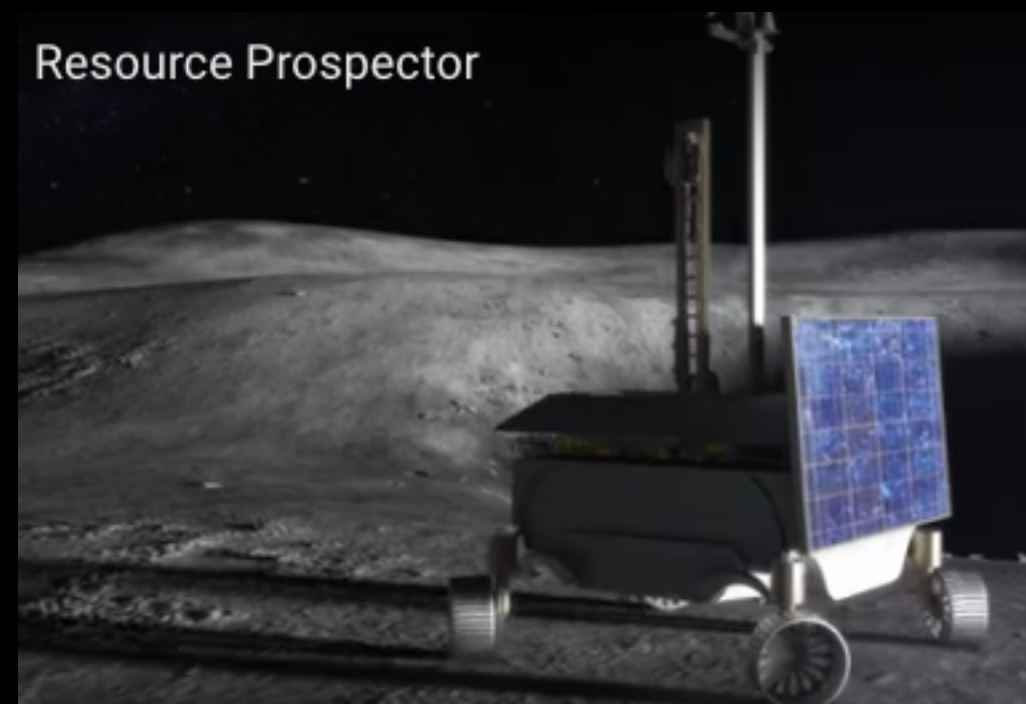
<https://nasa.github.io/openmct/>



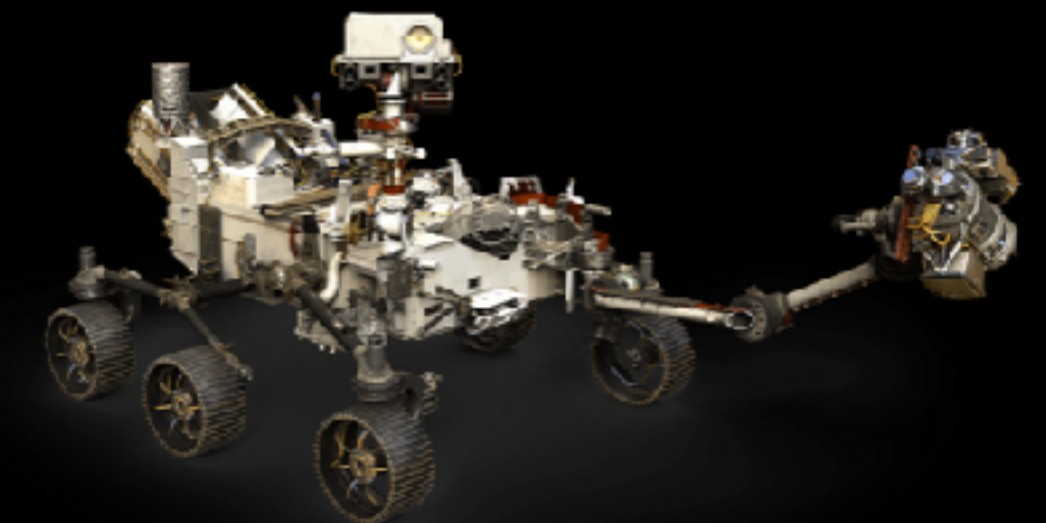
Initial Mission Users



Jason-3



Resource Prospector



Mars 2020
(expected testbed)

<https://nasa.github.io/openmct/>



All Your Data in One Place

A layout is a composition of data objects

Search your Data Objects

Browse your Data Objects

Inspect your Data Objects

The screenshot displays the NASA MSL data visualization interface. The main area contains several plots and a table of data. The left sidebar shows a tree view of data objects, and the right sidebar shows the properties of the selected object.

CH MSL Layout 2

DMX-1101 - EHA_RT_PROD_CNT

D-1791 - CMD_SAR_READ_MEM_LOC_1

DMX-1021 - EHA_REC_NUM_ALW...

D-1794 - CMD_SAR_READ_MEM_LOC_4

F-0840 - FSW_IDLE_SCRUB_ERR_ADDR_2

Table of Data:

ID	Title	Value	SCET
P-0219	PWR_RDE_SENSED	1	2016-21
R-0005	RAD_OP_STATE	1	2016-21
R-0047	RAD_UT_INDEX	744	2016-21
R-0024	RAD_DATA_RATE	0	2016-21
D-2199	DMD_UNSENT_RAD_DATA	14448	2016-21
R-0034	RAD_STM_WORD2_WORDS	505672470	2016-21
R-0236	RAD_RFE_PDU_15V_NEG_CURRENT	-0.08712095022201538	2016-21
R-0224	RAD_PDU_RDE_5_L_P	1.7924302816390991	2016-21
R-0249	RAD_DPU_3_3V_DIG_VOLTAGE	3.3047077665792236	2016-21
R-0238	RAD_RBE_PDU_13_5V_CURRENT	0.6470895734024048	2016-21
R-0019	RAD_SEQUENCE_AND_MASTER_FLAGS	33224	2016-21
R-0027	RAD_RPM_COUNTER	17511	2016-21
R-0175	RAD_HPCL_MIXER_TEMP	13.13481330871582	2016-21
A-0039	ICE_RFE_TEMP_5	23.01238854264858	2016-21
R-0134	RAD_RFE_CTRL_BRD_TEMP	25.429784468604492	2016-21
R-0140	RAD_RFE_1_MID_RANGE_TEMP	20.239271205731335	2016-21
R-0143	RAD_RFE_2_MID_RANGE_TEMP	20.118951848773155	2016-21
R-0146	RAD_RFE_3_MID_RANGE_TEMP	19.950138252678272	2016-21
A-0033	ICE_RFE_RDE_TEMP_1	15.33680941141956	2016-21
A-0043	ICE_RFE_RDE_TEMP_2	14.811549724013275	2016-21
A-0052	SPIN_PROFILE_ACC		
A-0050	SPIN_PROFILE_LAST_RATE_CMD		
A-0051	SPIN_PROFILE_TARGET_RATE		
A-0117	ICE_STATE		
A-0001	ICE_ERROR_FLAGS		
A-0002	ICE_CMD_ECHO		
RBA			
A-0013	ICE_RBA_ROOM_MOT_PHASE		

INSPECTION

PROPERTIES

TITLE: CH MSL Layout 2

UPDATED: 2016-01-21 17:43:47 UTC

TYPE: Display Layout

LOCATION: MSL Users > cfhacska

2015-300T06:58:42.617 to 2015-300T15:39:27.246

2015-300T06:58:42.617 2015-300T09:03:53.774 2015-300T11:19:04.391 2015-300T13:29:16.009 2015-300T15:39:27.246

VISTA

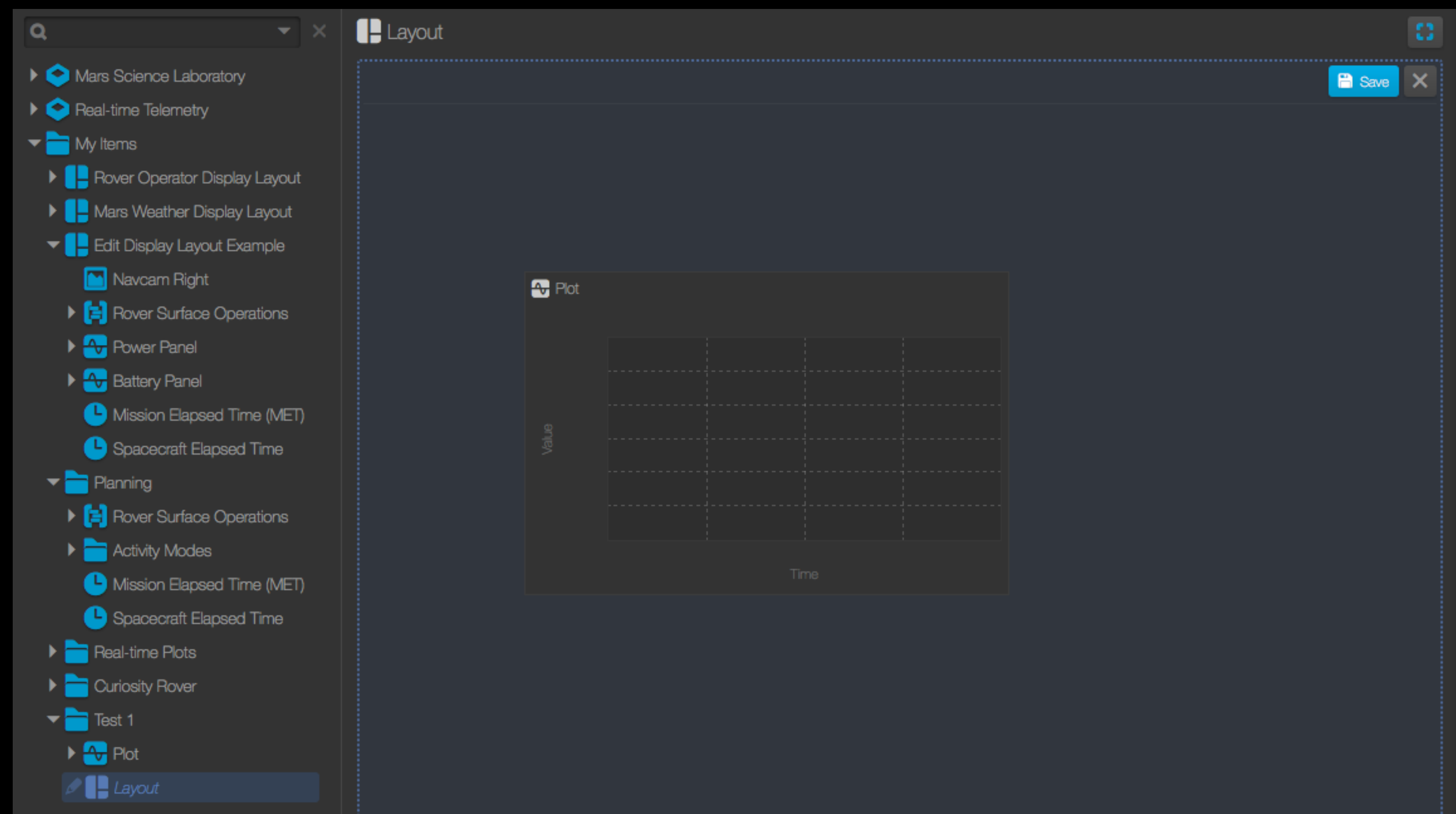
<https://nasa.github.io/openmct/>



Create & Compose



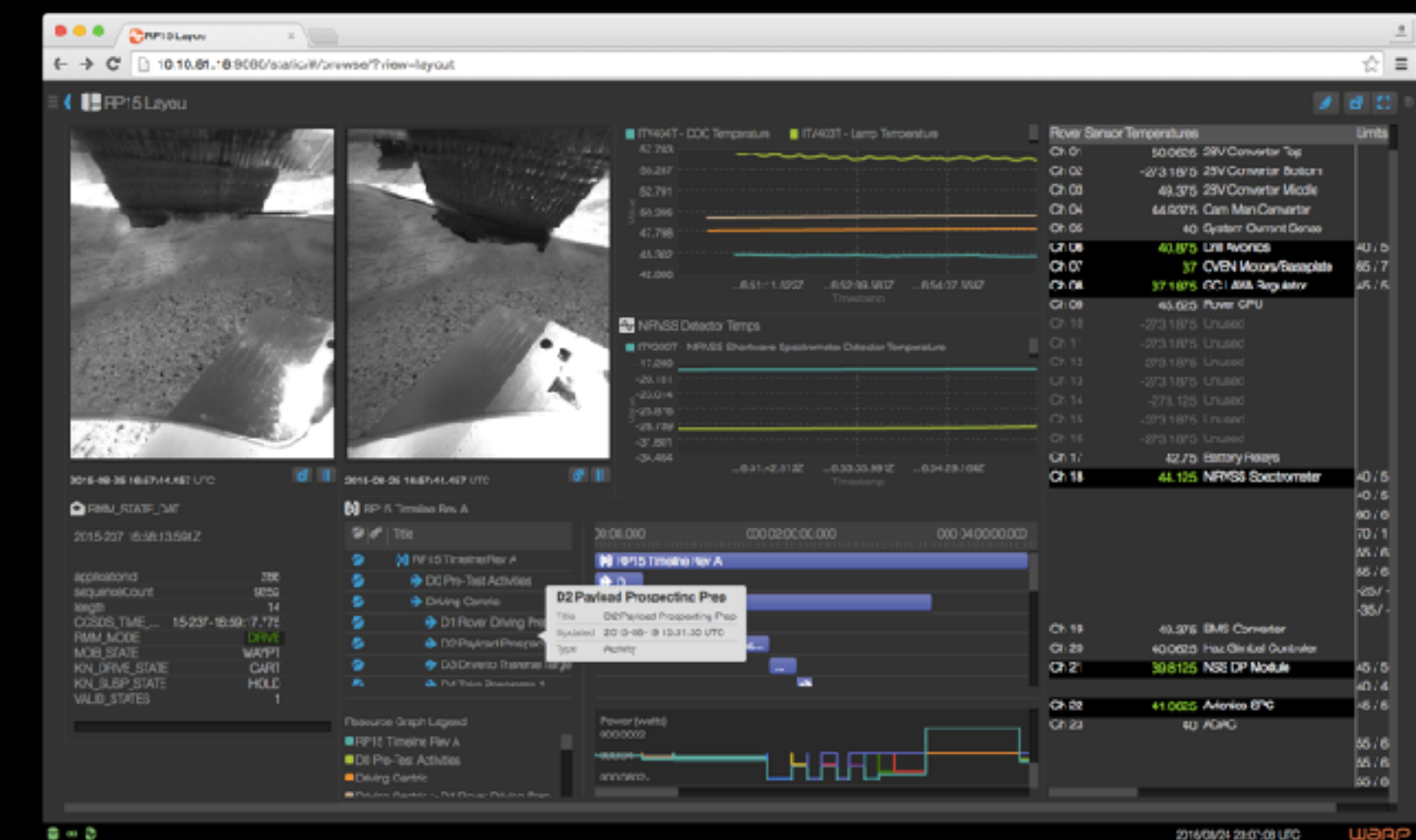
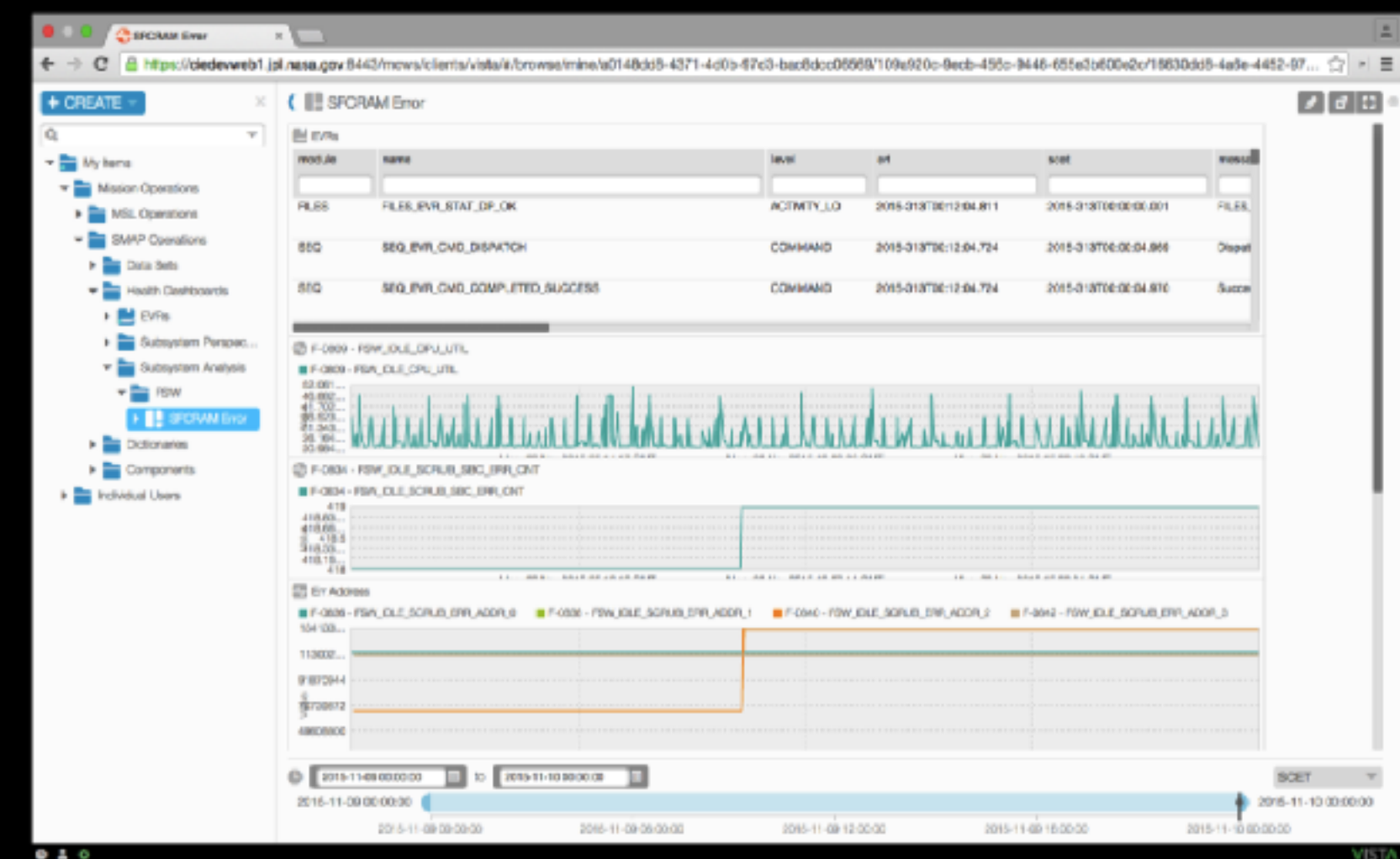
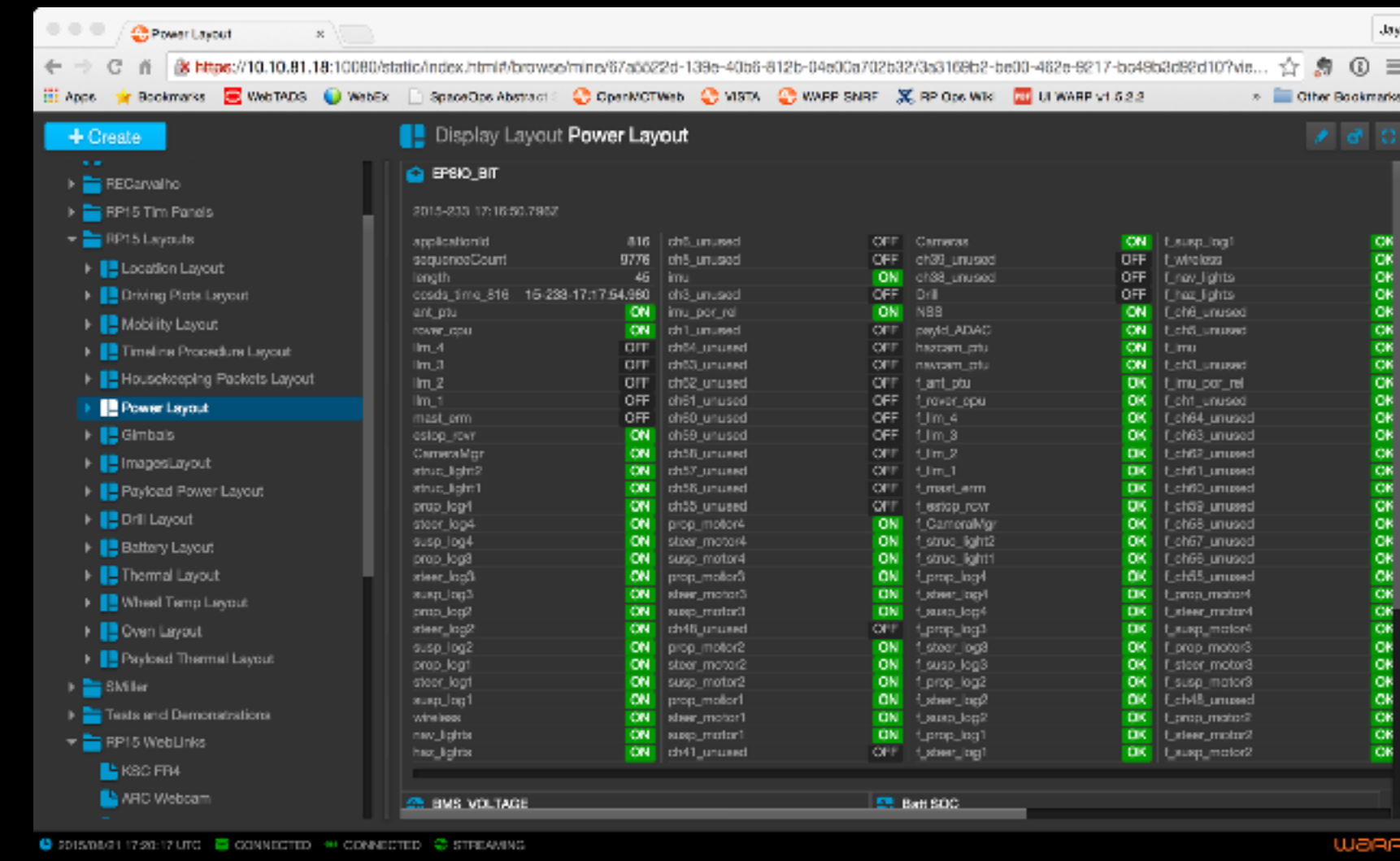
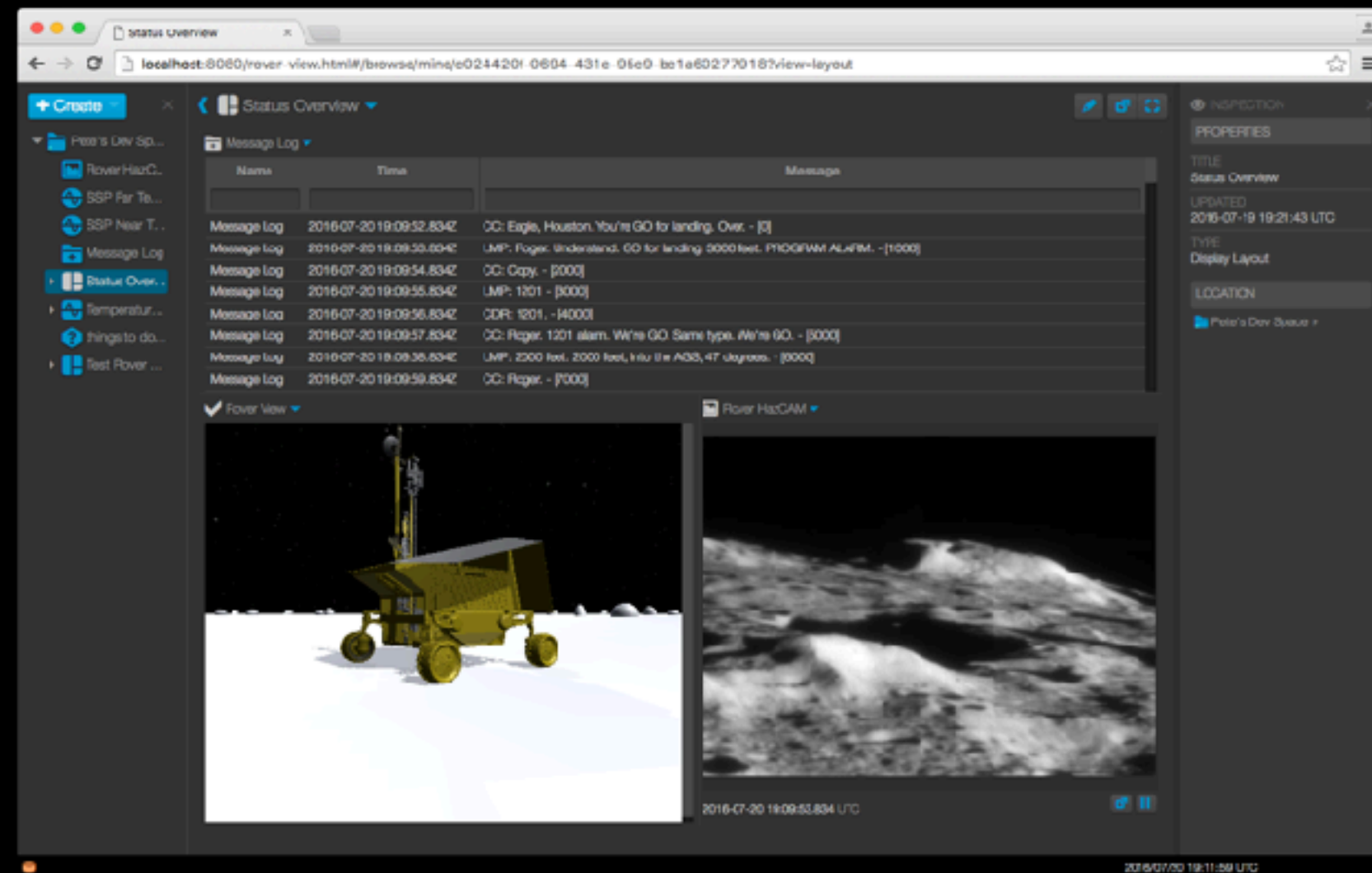
Example of user object types



Layout is the users canvas



User-Built Compositions





User Testing



2015/08/21 10:05 AM 66%

<https://192.168.1.107:10080/static/index.html#/browse/mir>

+ Create

- Packets
- My Items
 - RP15 Subsystem Modes
 - RP15 Timeline Rev A
 - RECarvalho
 - RP15 Tim Panels
 - RP15 Layouts
 - SMiller
 - Tests and Demonstrations
 - RP15 WebLinks
 - RP15 Clocks and Timers
 - AMCook
 - RP15 Sys
 - RoverSys
 - WM

Display Layout Battery

Rover Mode

trmm_mode	SAFE
mob_state	STOP
kin_drive_state	OFF
kin_susp_state	OFF
Estop	0.000
Pitch	- 0.039 rad
Roll	ai - 0.023 rad
Ride Ht	- 0.346 m
Tim Filter	- to_highrate tbl(*)
Data Rate	BAU... 900000.000

Battery SOC

STATE_OF_CHARGE	1593.000
MIN_CELL_VOLTAGE	2.000
MAX_CELL_VOLTAGE	3.000
AVG_CELL_VOLTAGE	4.000

BMSIO_DATA_DAT

No updates

applicationId	
sequenceCount	
length	
timestamp	
CONTROL_EN	
ARM_FIRE_DEBUG	
MANUAL_BALANCING_EN	
ARM_FIRE_BALANCING	

BMSIO_DETAIL_DAT

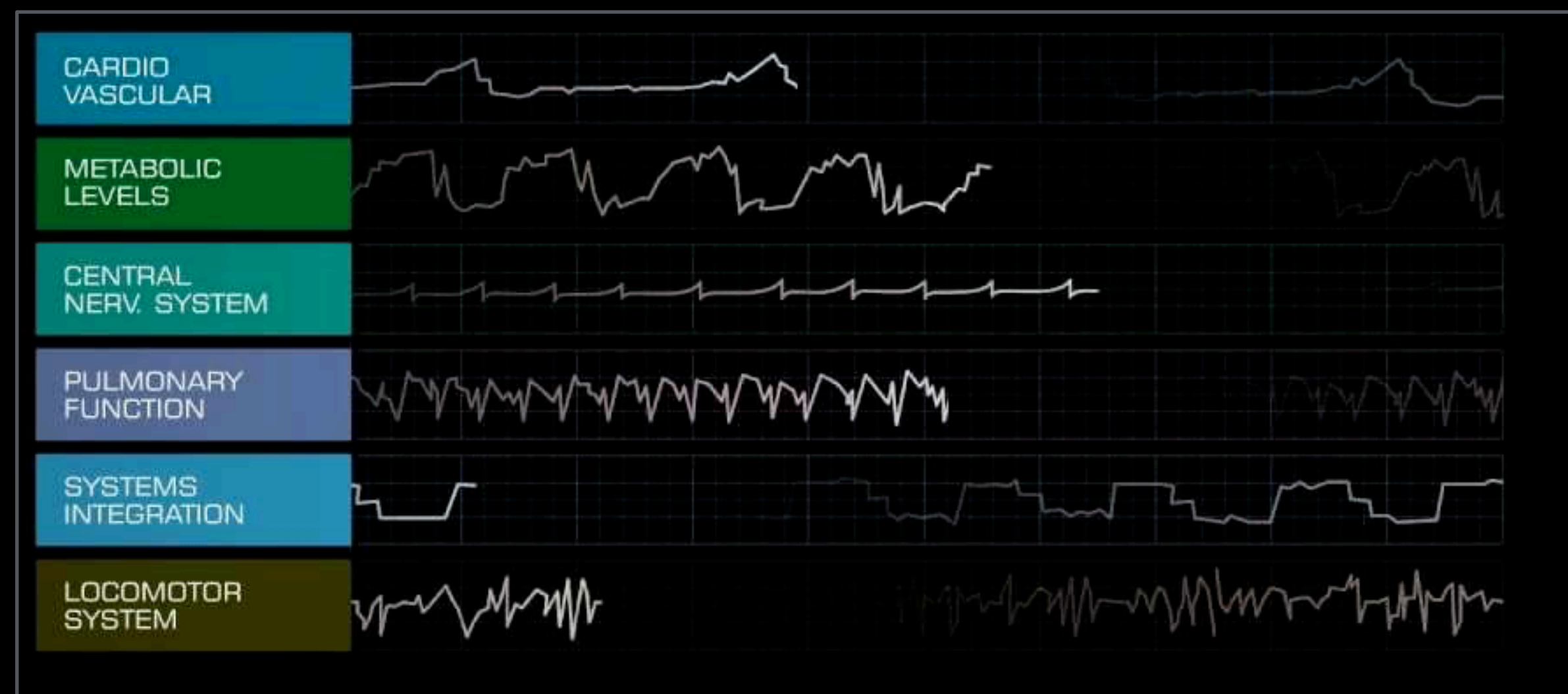
2015/08/21 10:05:14.797Z

applicationId	901	CELL_VOLT_S3_C2	998	CELL_TEMP_S1_C05	364
sequenceCount	1090	CELL_VOLT_S3_C3	998	CELL_TEMP_S1_C06	359
length	229	CELL_VOLT_S3_C4	998	CELL_TEMP_S1_C07	359

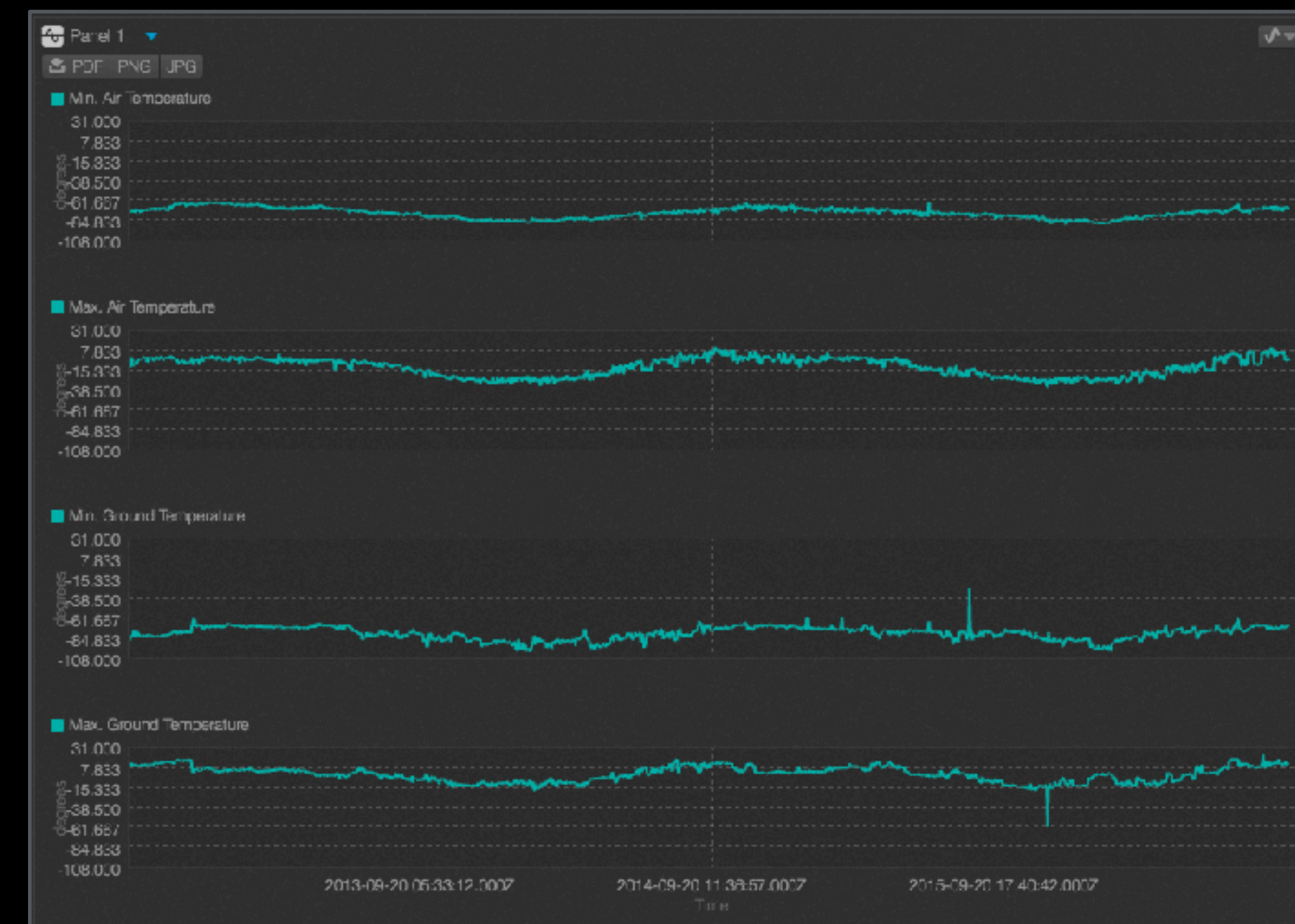
2015/08/21 10:05:14 UTC CONNECTED CONNECTED STREAMING WARP



For Fun



2001: A Space Odyssey

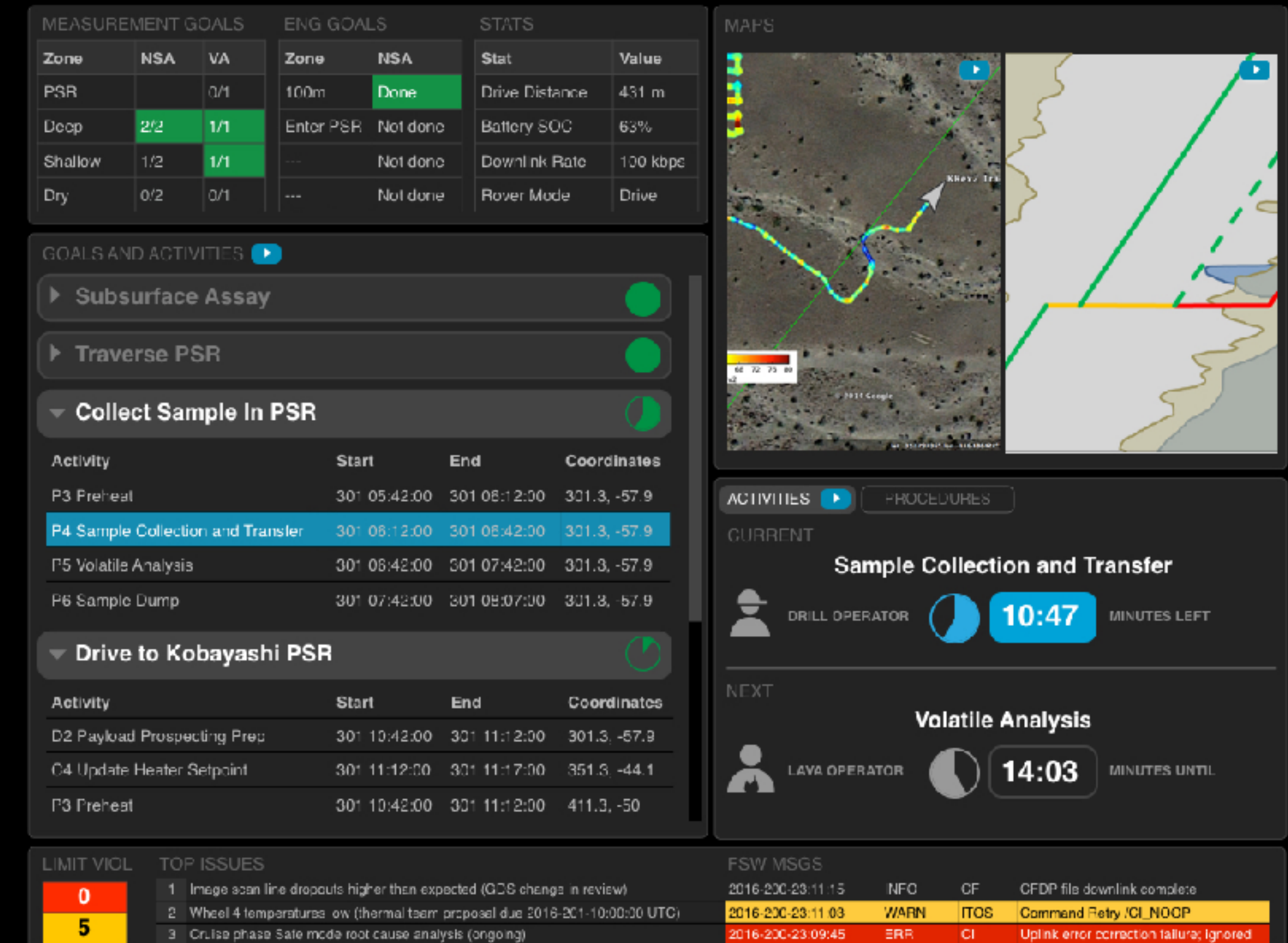


Open MCT



Sprint

GV Style Design Sprint





The Community

<https://nasa.github.io/openmct/>

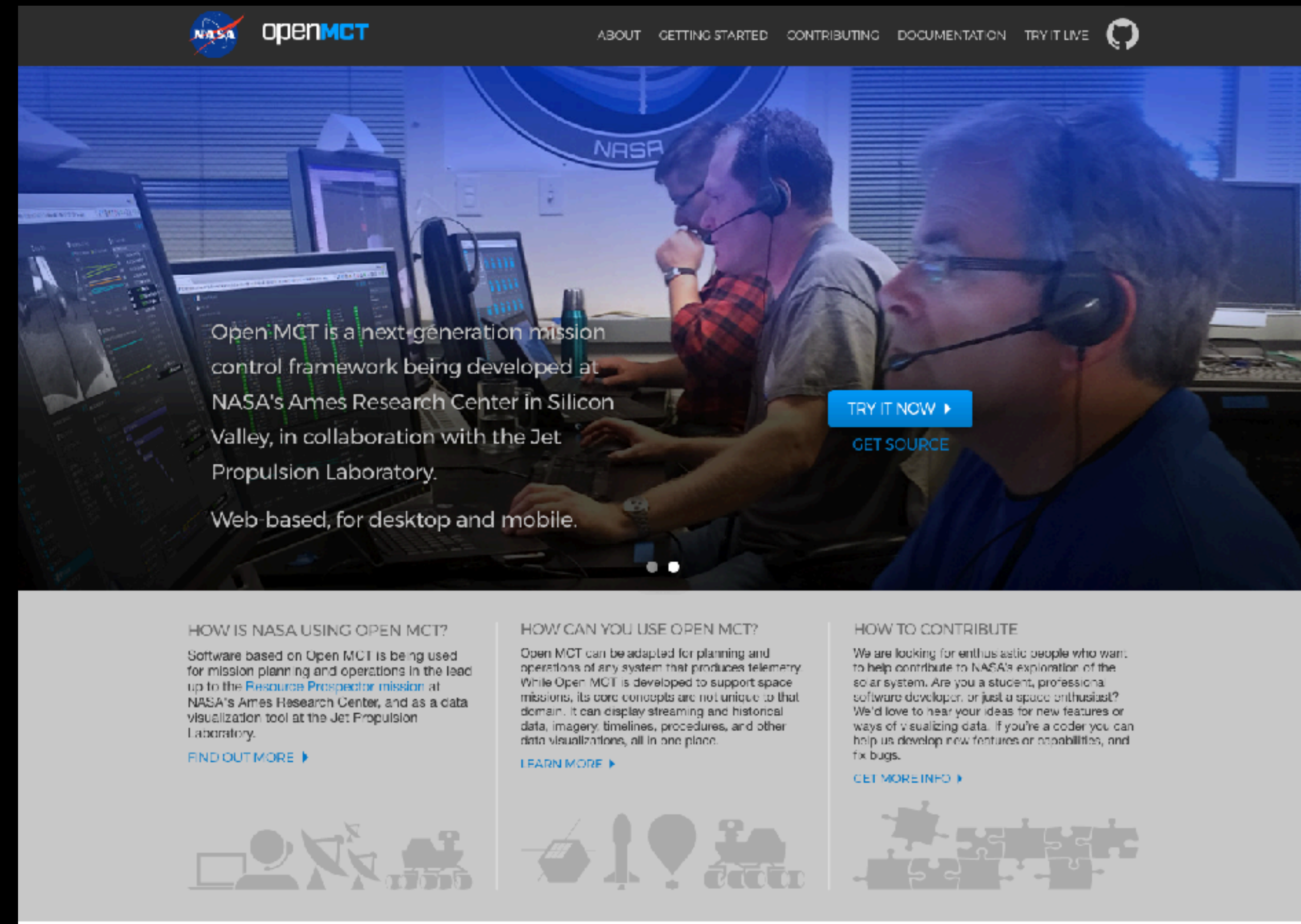
60 Visitors per week then..

User Reddit Post

20k visitors in two days

Outside contributors

Collaborations inside and outside of NASA that were not possible or practical before open source





The Role of Failure

“Failure is not an option” - Gene Kranz

Referring to human space flight operations



Design Thinking

...is now an accepted part of our organization, though it is only practiced by a small number of teams.

My team is moving design thinking from software, where we first established it, to the design and development of the mission system for a lunar prospecting rover.

“Say it then sim it”